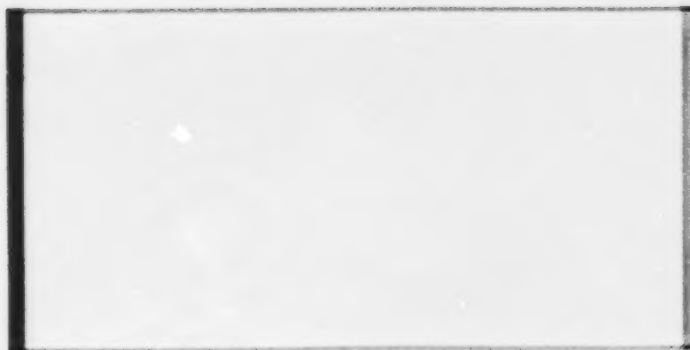


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WIND AND ICE LOADS ON DISTRIBUTION
LINES - A LOAD MONITORING SITE
NEAR ORANGEVILLE (Report No 1)

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Reliability
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Mechanical Research Department

ABSTRACT

The instrumentation system installed in February 1985 for measuring wind and ice loads on a distribution line at a site near Orangeville is described in detail. The results of the analysis of two ice storms are discussed. The maximum equivalent radial ice observed at the site was about 0.6 inch. The maximum 15-minute mean wind speed and the corresponding 2-second gust measured were 37 mph and 40 mph respectively.

job	file	date	report no.
740621-174-041 740621-363-041	825.151	November 11, 1985	85-291-K



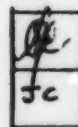
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EXECUTIVE SUMMARY

WIND AND ICE LOADS ON DISTRIBUTION LINES -
A LOAD MONITORING SITE NEAR ORANGEVILLE
(Report No 1)

S.G. Krishnasamy
Applied Structural & Solid Mechanics Section
Mechanical Research Department

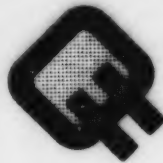
The objective of the Ontario Hydro's wind and ice load monitoring program is to assist in the probability-based design of overhead power lines by establishing a province wide data base. As part of a long range program to establish data base Research and Distribution System Divisions have initiated a field program to establish a test site near Orangeville for measuring wind and ice loads on distribution lines. The site has been operational since February 1985. In this report the wind and ice load monitoring system developed for overhead distribution lines is described. Preliminary analysis has been done on two ice storms recorded during February and March 1985. The maximum equivalent radial ice observed at the site was about 0.6 inch. The maximum 15-minute mean wind speed and the corresponding 2-second gust measured were 37 mph and 48 mph respectively. The wind and ice load monitoring is continuing.



job	740621-174-041 740621-363-041	file	825.151	date	November 11, 1985	report no.	85-291-K
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**ontario hydro
research division**

To Mr. F.J. Kee
Director of Research

Mr. T.L. Bakonyi
Manager of Distribution Planning & Design

**WIND AND ICE LOADS ON DISTRIBUTION LINES -
A LOAD MONITORING SITE NEAR ORANGEVILLE
(Report No 1)**

1.0 INTRODUCTION

Design of overhead lines against wind and ice loadings is achieved using loadings mainly derived from past experience and simplified analytical models. For most types of loading involving wind and ice, there are limited field data available and broad guidelines are used to ensure safe designs. While this is a safe approach there may be undue conservatism in the existing design practice.

Recognizing the need for a better understanding of the effect of weather related loads on overhead power lines Ontario Hydro has established four test sites in Southern Ontario/1,2/ to measure wind and ice loads on transmission lines on a continuous basis. The measurement systems record along-the-line load, across-the-line load and vertical load due to wind and ice acting on the conductors as well as meteorological data such as wind speed, wind direction, temperature, precipitation, etc. These measurements are contributing to a data base from which improved design standards may evolve and on which new probabilistic design methods may be based.

As part of a long range program to establish data bases for probability based design of distribution lines Research and Distribution System Divisions has initiated a field program to establish a test site for monitoring wind and ice loads on overhead lines.

In this report the wind and ice load monitoring system developed for overhead distribution lines is described. The system is a modified version of the one being used for the overhead transmission lines/2/. The instrument package has been in service at a site near Orangeville (Figure 1) from the beginning of 1985 and consists of a load measuring instrumentation, an ice-free anemometer, a precipitation gauge and a temperature probe. Some typical data records gathered at the site have also been analyzed.

The prototype ice-free anemometer developed by Metrex Instruments is being field tested under the joint sponsorship of Ontario Hydro, CEA and Metrex Instruments. The preliminary results of this study will also be briefly discussed.

2.0 POLE LOAD MEASURING AND DATA ACQUISITION (POLDA) SYSTEM

The various components such as load measuring instrumentation, wind sensor, data acquisition instrumentation etc, will be described below in some detail. The specifications on the various instruments used are given in Table I.

2.1 Load Measuring Instrumentation

The load measuring instrumentation (Figure 2) consists of a heavy duty uniaxial commercial load cell attached to the pole cross arm through a universal joint to measure the axial insulator string load (P) and two rotary transducers (Figure 2) mounted on the universal joint to measure along-the-line (longitudinal, ϕ_1) and across-the-line (transverse, ϕ_2) angles of the insulator string. Combining the insulator string load with the transverse and longitudinal swing angles, as shown below, the vertical, longitudinal and transverse components of the conductor load can be calculated.

Vertical Load	$= (P - P_1) \cos \phi_1 \cos \phi_2$
Longitudinal (along-the-line) load	$= P \sin \phi_1 \cos \phi_2$
Transverse (across-the-line) load	$= P \cos \phi_1 \sin \phi_2$

P_1 is the total weight of bare conductor for the whole span. The instrumentation is protected against snow, ice and rain by a shroud as shown in Figure 3 (a and b).

2.2 Wind Sensors

The wind sensor (manufactured by Hydro Tech, Figure 4) consists of a rotor and a wane for measuring wind speed and direction respectively and is equipped with a 1500 watt heater to keep the instruments ice free in the winter.

A prototype ice-free anemometer (developed by Metrex Instruments) is being field tested jointly by Ontario Hydro, Canadian Electrical Association and Metrex Instruments. This anemometer is equipped with a 50 watt heater to keep it ice-free and has a single sensor to monitor wind speed and direction. The specification details of this prototype sensor are given in Table I.

The Hydro Tech anemometer is also being used as a reference sensor to evaluate the Metrex anemometer. The wind speed and direction signals from the Hydro Tech anemometer will be designated as S1 and D1 and the corresponding signals from the Metrex Instruments will be referred to as S2 and D2.

2.3 Data Acquisition Instrumentation

The data acquisition instrumentation, basically consisting of signal conditioner, a data analyzer and a digital data logger, will be described below in some detail.

2.3.1 Signal Conditioner

The signal conditioner is capable of handling a total of eight signals - insulator string load, across-the-line angle, along-the-line angle, wind speed (2 values), wind direction (2 values), air temperature and precipitation. It has provisions for adjusting zero offset, checking calibration and to monitor the input and output of various signals.

2.3.2 Data Analyzer

Data are gathered on insulator string load, across-the-line angle, along-the-line angle, wind speed (2), wind direction (2), air temperature and precipitation. Because the data (except air temperature and precipitation which are monitored once in every 10 minutes) are averaged over a period of two seconds, 447¹ values are collected for each set of data for every 15 minutes².

¹ Strictly there should be a total of 450 values for a period of 15 min if the averaging time is 2 s. However, the remaining 6 s period is allocated for data analysis and storage.

² The averaging period will be changed from 15 min to 10 min in the summer of 1985 to be consistent with international guidelines.

3

The mean, peak and standard deviation for insulator string load, across-the-line angle, along-the-line angle, wind speed S1 and wind direction D1 and the mean and peak values for wind speed S2 and wind direction D2 are calculated by the analyzer (Figure 5) for every 15 min period. Also recorded are the simultaneous values of insulator string load, along-the-line angle, across-the-line angle, wind speed and direction corresponding to the maximum across-the-line angle during every 15 min period.

2.3.3 Digital Cassette Data Logger

At the end of every 15 min, the data logger (Figure 5) is activated to store the data coming from the data analyzer. At the rate of one set of data every 15 min, the cassette tape will last about six weeks.

During an ice storm, if the amount of ice on the conductor exceeds a preset threshold, the data analyzer will switch the data logger into a faster mode. This arrangement allows collection of more detailed information on conductor icing and possibly galloping.

2.3.4 Data Reader

The data reader along with a personal computer (2 EVS-2001) is used to interpret the data gathered at the load measuring site. A computer program developed for the data analysis transforms the data into a convenient format for storage.

3.0 INSTALLATION OF MEASURING AND ACQUISITION INSTRUMENTS

A general view of the POLDA System at Orangeville test site and related details are given in Figure 6.

The load measuring instrument is mounted between the cross-arm and the insulator string (Figure 3) such that it measures only the load on the conductor. The wind sensors are mounted on a mast on the top of the pole (Figure 3 and 6). The precipitation gauge (Figure 7) is mounted on the roof of the instrument cabin (Figure 8).

The recording instruments are housed in a cabin (Figures 5, 8 and 9) located at the bottom of the pole. All the instruments, except the two wind sensors and the precipitation gauge, are powered by a heavy duty battery which in turn is kept charged by a 110 Vac power supply. The cabin temperature is maintained at about 20°C. The cabin, the instruments and the data loggers are properly grounded and protected against damage due to lightning.

The measuring and recording instruments are integrated as shown in Figure 10. The signals from the various instruments are passed through surge protectors before entering the signal conditioner and data analyzer. The analyzed data are stored in the data logger.

The system has been in operation since early 1985.

3.1 Salient Features of the Digital Data Logging System

The following are some of the important features of the digital data logger in operation at the Orangeville site:

- (a) If needed the data logger is capable of operating at temperatures down to -40°C .
- (b) The microprocessor-based analyzer is designed to average data over a two-second period, which is essential to observe the dynamic response of the line due to turbulent wind.
- (c) The analyzer is capable of providing statistical information such as mean, maximum and standard deviation.
- (d) Data logger can be set to switch to a faster recording mode to collect data on ice storms.

4.0 A TYPICAL DATA RECORD FROM ORANGEVILLE TEST SITE

To demonstrate the usefulness of the wind and ice load monitoring system discussed above a typical record is shown in Figure 11.

The first column in Figure 11 shows the day and the time of the recording while the temperature is given in the second column. The number of samples, a total of 447 in 15 minutes, in the third column are taken at the rate of one every two seconds. The wind and load data are divided into five main categories. The first category provides the 15-minute values of mean wind speed, wind direction, across-the-line angle, along-the-line angle and the insulator string load while the corresponding peak values are given in the second category. Given in the third category are the simultaneous values of insulator string load, along-the-line angle, wind speed and direction, each corresponding to the maximum across-the-line angle during every 15 minute period. The fourth category provides the standard deviation values for wind speed, across-the-line angle, along-the-line angle and insulator string load. The four columns in the fifth category provide the average wind direction

and speed, and peak wind direction and speed measured by Metrex Instrument prototype ice-free anemometer. The precipitation measurement, taken at the end of every 15 minute period, is shown in the last column.

Wind direction is tabulated by dividing a compass into sixteen sectors as shown in Figure 12. A typical sector AOB shown in the figure represents the direction ranging between $33-3/4^{\circ}$, and $56-1/4^{\circ}$. The complete description of all the twelve sectors is given in Figure 12. Each sector has a 'counter' which is incremented whenever the wind direction is in that sector. At the end of the 15 min averaging period the direction of the sector with the highest number of occurrences is taken as the mean (or prevailing) wind direction. The 'peak' wind direction is the value measured during the 2 s period in which the peak wind speed occurred.

4.1 Preliminary Analysis of Wind and Conductor Load Data During a Typical Storm

Since the load monitoring station became operational in the early part of 1985 two ice storms with differing severity were recorded at the test site. A brief summary of these storms is given in Table II and the storm that occurred on March 31-April 1, 1985 has been analyzed in some detail. It should be pointed out that during both of these storms there was some malfunctioning in the anemometers as indicated in Table II.

The ice storm (Figure 13), the details of which are given below, started in the early hours of March 31 and lasted for almost 24 h before the temperature rose to above freezing and the ice shedding started. The maximum ice build up and the 15 min average wind speed during the storm were approximately 0.6 inch radial (approximately 1.2 lbs/ft) and 37 mph respectively. The highest 2 s gust recorded during the storm was about 48 mph producing a maximum across-the-line insulator swing angle of about 50° .

When the freezing precipitation started during the early hours of March 31, 1985, the 15 min average wind speed was about 18 mph and the temperature was just below freezing. The ice continued to accrete for about 22 hrs (reaching a maximum of 0.6 inch radial) during most of which period the temperature remained below freezing. When the temperature rose well above freezing point at about 2200 hrs on March 31, 1985 the ice shedding process set in and the ice accretion on the conductor was reduced to about 0.15 inch radial. The wind speed measurements during the same period are not reliable because of the malfunctioning of the wind sensor heaters leading to probable icing of the anemometers.

5.0 PERFORMANCE OF WIND SENSORS DURING ICE STORMS

As mentioned earlier two wind sensors, a standard ice-free anemometer (Hydrotech) and a prototype ice-free anemometer (Metrex Instruments), are being used for monitoring wind speed and direction. The Metrex prototype anemometer is being field tested jointly by Ontario Hydro, Canadian Electrical Association and Metrex Instruments. The Metrex anemometer is a low power (approximately 50 Watts) sensor while the Hydraulic instrument requires up to 1500 watts for ice-free operation.

During the March 31 - April 1, 1985 ice storm the heaters for both the ice-free anemometers were not operational due to the following reasons. The heater circuit for the Hydrotec anemometer was not in service at the time of the storm because the controller for the heater was taken out for servicing. The heater for the Metrex anemometer was also not functional because of a bad connection in the circuit. Even though the heaters were not turned on during the freezing storm the anemometers were still operational as seen from Figure 13; however, the measurements are not reliable because of the ice build up on the sensors.

The wind sensors are expected to be back fully operational in the summer of this year.

6.0 SUMMARY AND CONCLUSIONS

The Research Division, in cooperation with Distribution Systems Division, has installed a wind and ice load measuring system on a 45 kV distribution line at a site near Orangeville for monitoring data on wind speed and direction, wind and ice loads, ambient temperature and precipitation. Two anemometers, (one made by Hydrotec and the other by Metrex Instruments) both equipped with heaters for ice-free operation, are being used to gather wind data. The Hydrotec anemometer is also being used as a reference sensor to verify the performance of the Metrex prototype anemometer which is being field tested under a joint sponsorship by Ontario Hydro, Canadian Electrical Association and Metrex Instruments.

Since the installation of the measuring system in the early part of 1985 data have been gathered on two ice storms. The analysis of the data gathered during two ice storms have provided the following information:

1. A maximum accumulation of 0.6 in equivalent radial ice, accompanied with a 15 min mean wind speed of 37 mph

(with a corresponding 2 s gust speed of 48 mph), was measured on April 1, 1985³.

2. The wind and ice load measuring system is functioning satisfactorily.
3. The heater circuits for both the anemometers failed to function during the ice storms due to some temporary causes, which are currently being corrected.
4. Due to the uncertainty in the wind speed measurements during the ice storms (Item 1) no performance comparisons were made between the Metrex and Hydrotec anemometers.

Both the anemometers are currently being serviced by the manufacturers to correct the defects in the heater circuits.

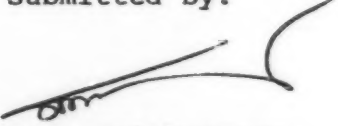
ACKNOWLEDGEMENTS

The cooperation of the Canadian Electrical Association and Metrex Instruments Ltd is very much appreciated in the field testing of the Metrex ice-free anemometer.

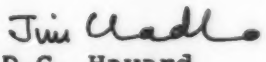
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SGK:ljh/lAg

³ The wind speed measurements are only approximate because of the ice build up on anemometers due to the malfunctioning of the heaters (refer to page 7.).

REFERENCES

1. S.G. Krishnasamy, "Measurement of Wind and Ice Loads on Overhead Transmission Lines (Progress Report No 4)", Ontario Hydro Research Division Report No 80-2-K, File 825.1216, February 21, 1980.
2. S.G. Krishnasamy, "Instrumentation for Collecting Wind and Ice Loads on High Voltage Overhead Transmission Lines", Ontario Hydro Research Division Report No 80-90-K, File 825.1216, February 27, 1980.

TABLE I

SPECIFICATIONS OF INSTRUMENTS IN THE POLDA SYSTEM

1) Data Reducer MK11

Manufacturer	Ontario Hydro Research Division
No Input Signals	6-9
No Output Signals	21-26
Power Requirement	5 Vdc, 110 mA
Input cycle time:	2 second min
Recording cycle:	15 minutes

2) Temperature Probe

Manufacturer	Ontario Hydro Research Division
Transducer:	PMI REF02 Voltage/Reference thermometer
Range:	-50C to 50C
Output Signal:	-5 to +5 Vdc

3) Precipitation Meter

Manufacturer	Weathertronics
Model:	6021-B - Tipping bucket
Resolution:	0.1 mm
Power Requirements:	11S Vdc, 500 watts
Output Signal:	per contact closure 20 m Vdc, cumulative output to 5 Vdc max and re-setting

4) Wind Speed/Direction Sensors

- | | |
|--------------------|--|
| a) Manufacturer | Hydro Tech |
| Model: | WS-3 and WD-3 |
| Range: | Speed: 0-200 KMH, Direction 0 - 360° |
| Excitation: | 5 Vdc (direction) |
| Calibrated Output: | 0-5 Vdc (both direction and speed) |
| b) Manufacturer | METREX |
| Model | Prototype design |
| Range | Speed: 0-100 knots |
| | Direction: 0-360° |
| Calibrated Output: | digital: dir 0-360°, speed 0-100 knots |
| | analog: dir 0-3.6 Vdc |
| | speed: 0-5 Vdc |

5) Load Cell

Manufacturer	LEBOW
Model	3169-108
Range:	3000 lbs
Excitation:	20 Vdc Max
Calibrated Output:	2 mV per volt input @ rated capacity

6) Swing Angle Transducer

(across the line)

Manufacturer	Pickering
Model	23300 - YZ-FO
	RVDT DC-DC
Range	±70 degrees
Excitation	6 VDC
Output	±2.8 Vdc @ max displacement

(Along the line)

Manufacturer	Trans-Tek Inc
Model	0241-000
	LVDT dc-dc
Range	±0.15 inch
Excitation	6-30 VDC
Output	2.1-10.7 Vdc FS

7) Digital Data Logger

Manufacturer	DATEL Systems Inc
Model	DL-2A2X
No of Channels	32 high level
Input Range	-5 V to +5 V
Power Supply Req	12 Vdc

TABLE II
ANALYSIS OF TWO ICE STORMS IN 1985 AT THE ORANGEVILLE DISTRIBUTION LINE LOAD MONITORING SITE

STORM NO	DATE AND TIME	MAXIMUM MEAN WIND SPEED (mph)	MAXIMUM PEAK WIND SPEED (mph)	MAXIMUM ACROSS-THE-LINE ANGLE (degrees)	MAXIMUM ALONG-THE-LINE ANGLE (degrees)	AMOUNT OF MAXIMUM EQUIVALENT RADIAL ICE (inch)	PREVAILING WIND DIRECTION	REMARKS
1	Feb 12/85 0700 hrs to Feb 13/85 1000 hrs	33	46	21	2	0.3	Approximately 60° to the line	anemometer heaters were not on due to circuit malfunctioning and hence the sensors were iced up leading to error in the wind data (for storm #2)
2	Mar 31/85 0000 hrs to Apr 1/85 0001 hrs	34	48	50	9	0.6	Approximately normal to the line	

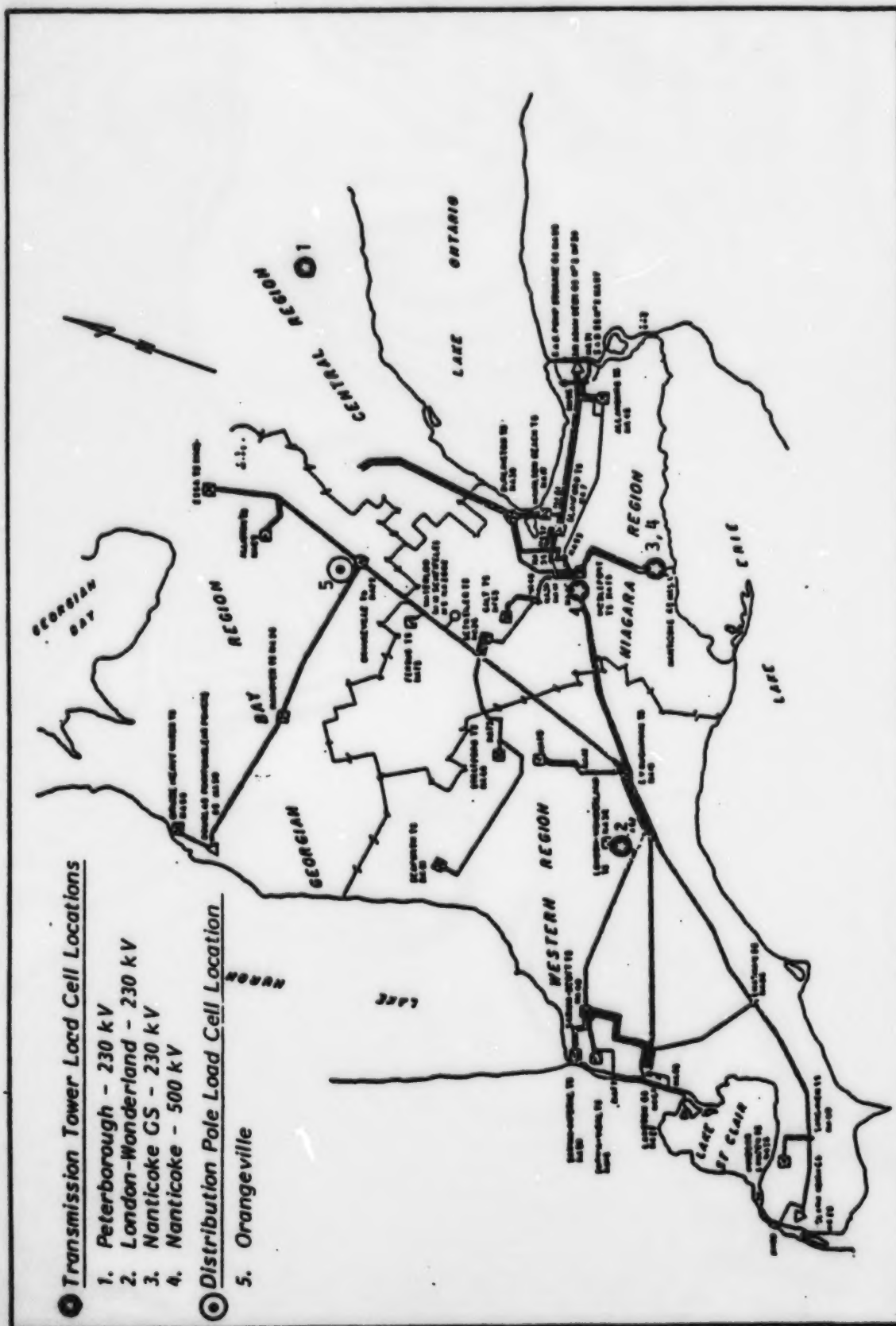


FIGURE 1
WIND AND ICE LOAD MONITORING LOCATIONS IN SOUTHERN ONTARIO (AS OF JULY 1985)

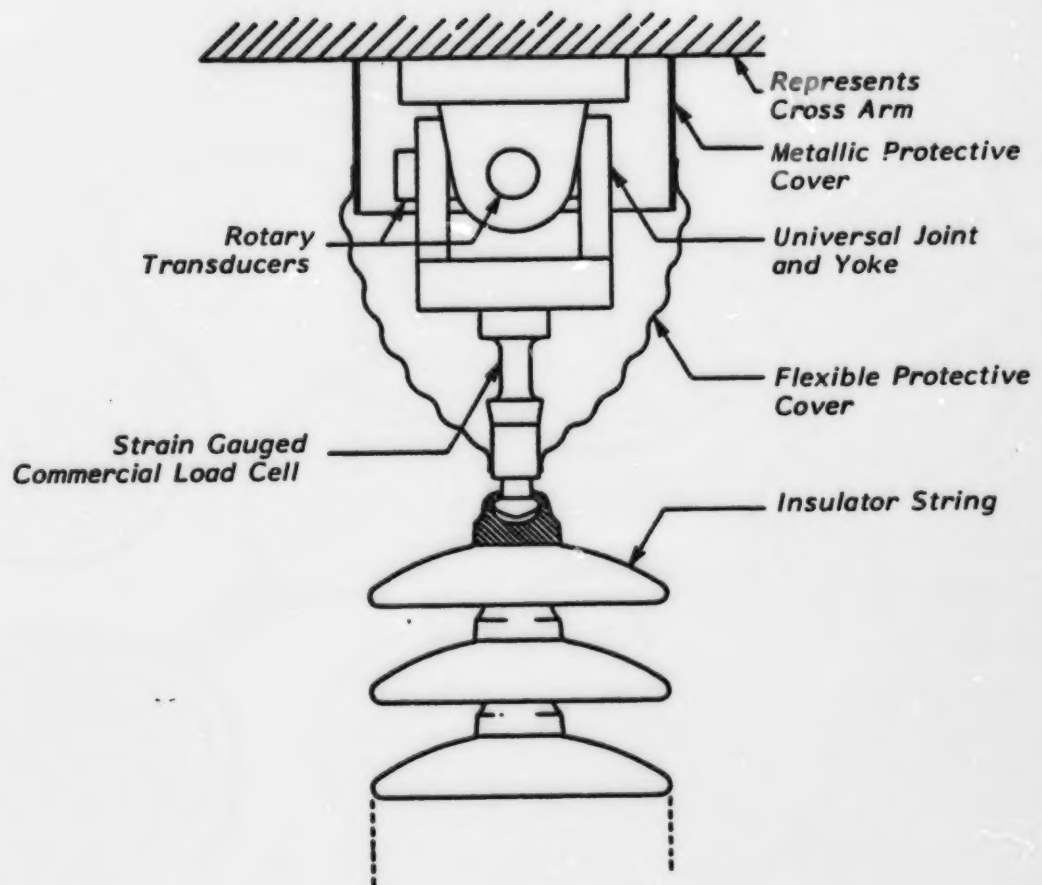


FIGURE 2
DETAILS ON LOAD MEASURING INSTRUMENT

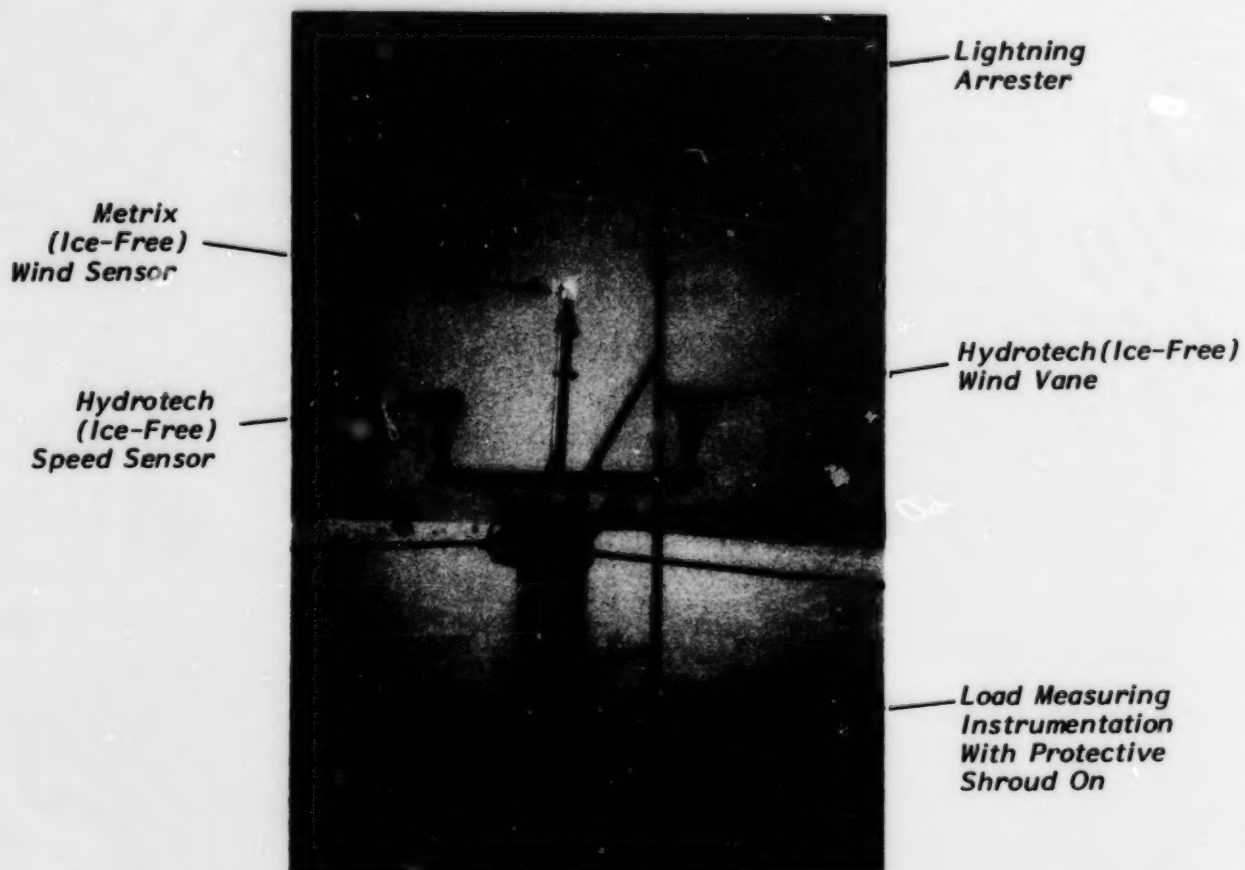


FIGURE 3(a)
WIND AND ICE LOAD INSTRUMENTATION AND WIND SENSORS
AT THE ORANGEVILLE TEST SITE

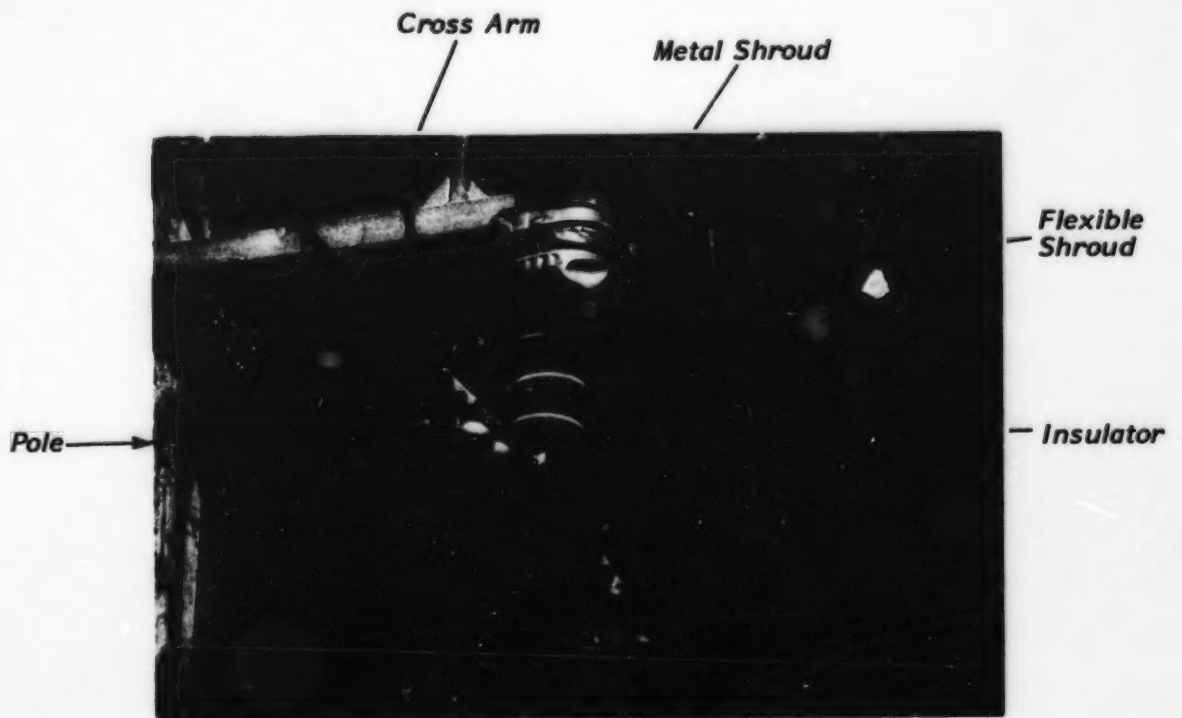


FIGURE 3 (b)
A CLOSE VIEW OF THE LOAD MEASURING INSTRUMENTATION



(a)



(b)

FIGURE 4
COMPONENTS OF THE (HYDROTECH) WIND SENSOR SYSTEM
USED AT THE ORANGEVILLE TEST SITE

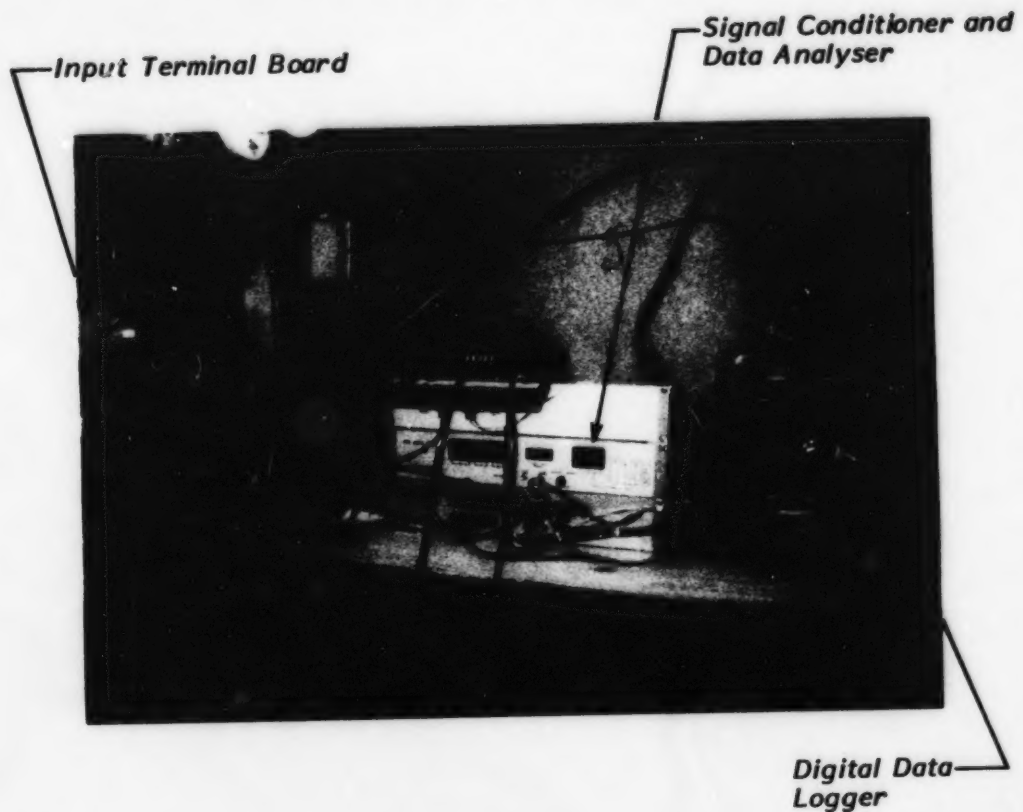
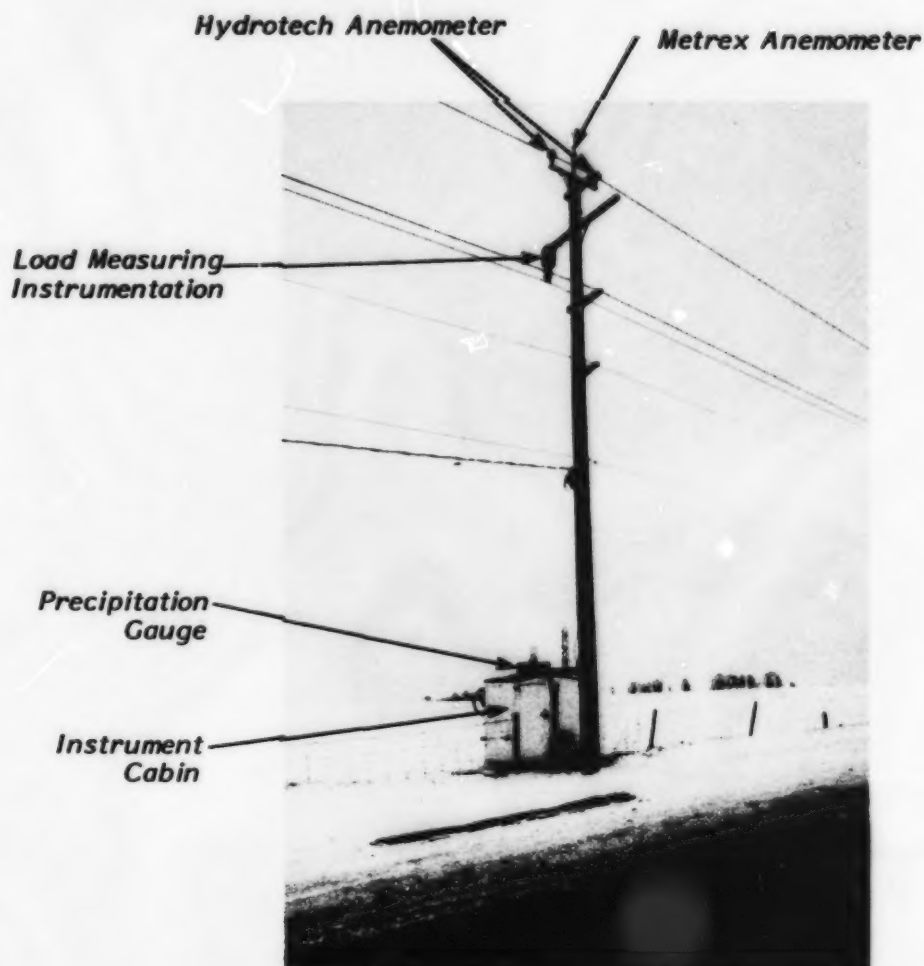


FIGURE 5
DATA ACQUISITION INSTRUMENTATION AT THE ORANGEVILLE SITE
(PARTIAL INSIDE VIEW OF THE INSTRUMENT CABIN)



(Lightning Arrester Not Shown)

FIGURE 6
AN OVERALL VIEW OF WIND AND ICE LOAD MONITORING
SITE AT ORANGEVILLE

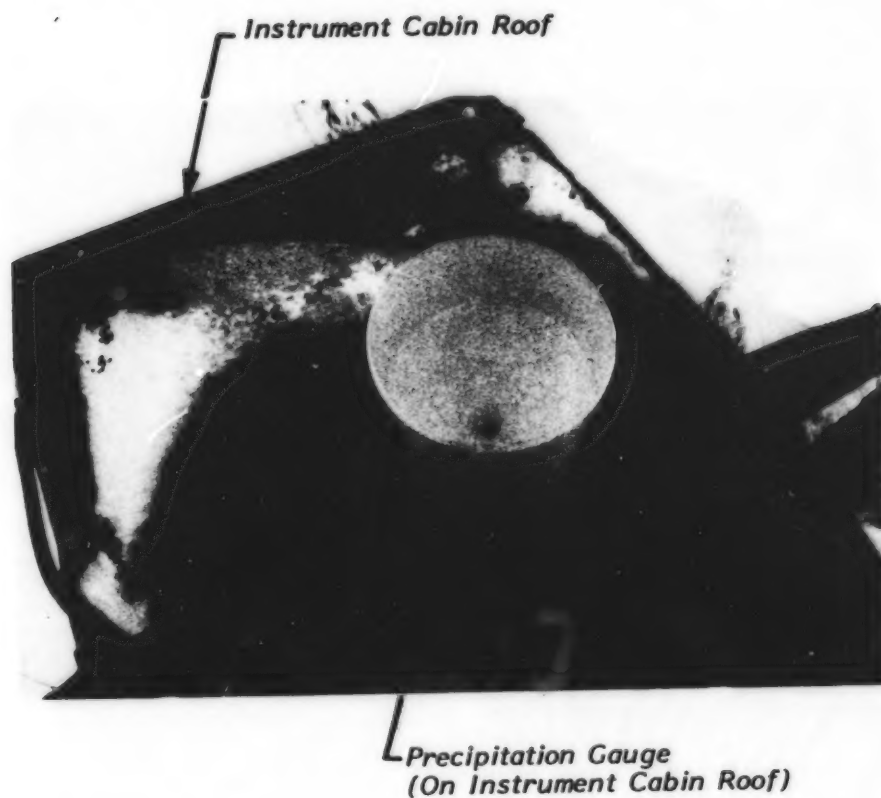


FIGURE 7
PRECIPITATION GAUGE AT THE ORANGEVILLE TEST SITE

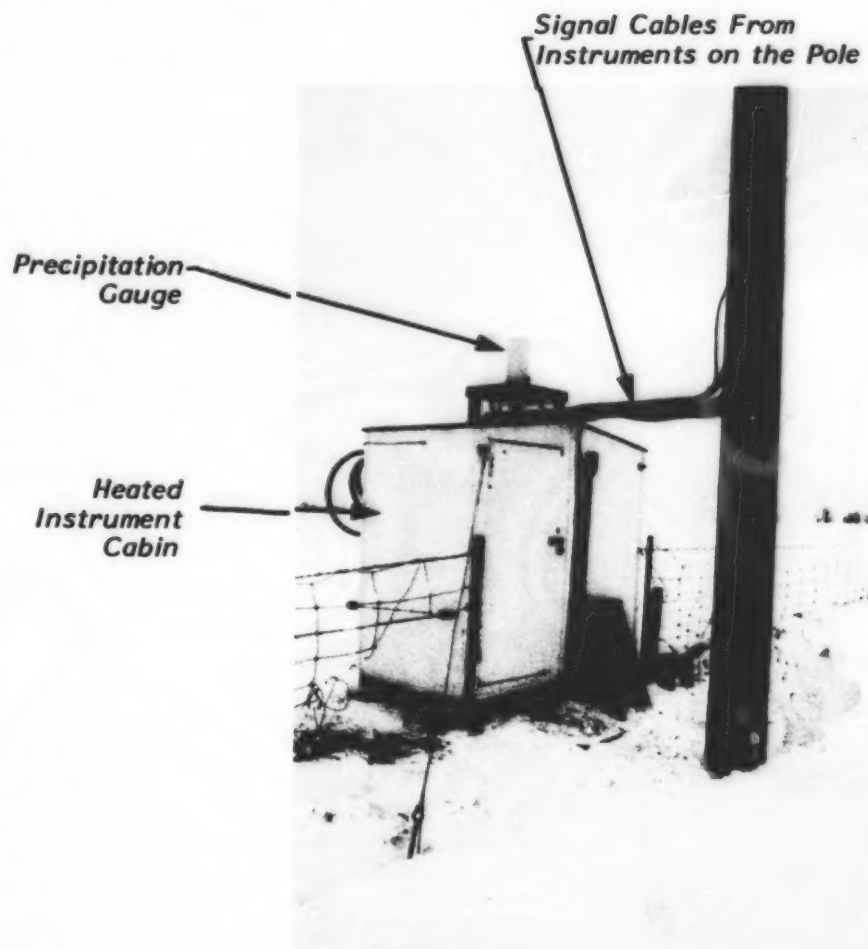


FIGURE 8
WIND AND ICE LOAD INSTRUMENTATION CABIN
AT ORANGEVILLE

Controller For Hydrotech
Wind Sensor



FIGURE 9
PARTIAL INSIDE VIEW OF THE INSTRUMENT CABIN
AT ORANGEVILLE

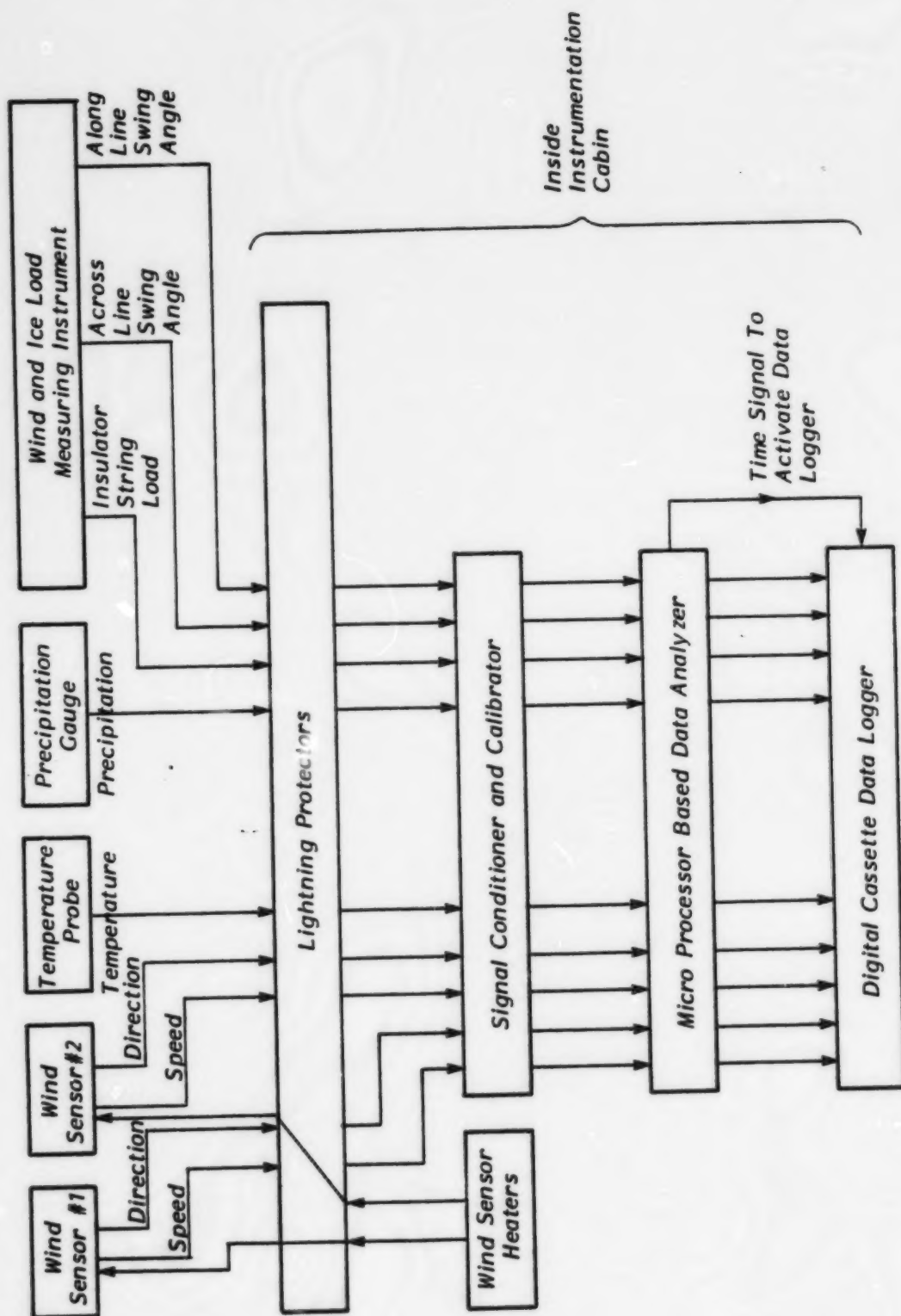


FIGURE 10
A SCHEMATIC OF LOAD MEASURING AND DATA ACQUISITION SYSTEM AT ORANGEVILLE

Day	Time (hrs)	Temperature (°C)	CATEGORY 1										CATEGORY 2										CATEGORY 3										CATEGORY 4										CATEGORY 5									
			Mean Values					Peak Values					Span Factor Data					Statistical Parameters					Insulator Load					Sensor #2																								
			Number of Samples (in 15 minutes)	Mean Wind Direction	Mean Wind Speed (mph)	Mean Across-the-Line Angle (deg)	Mean Along-the-Line Angle (deg)	Mean Insulator Load (lbs)	Wind Direction Corresponding to Peak Wind Speed	Peak Wind Speed (mph)	Peak Across-the-Line Angle (deg)	Peak Along-the-Line Angle (deg)	Peak Insulator Load (lbs)	Wind Direction Corresponding to Peak Across-the-Line Angle	Peak Speed Corresponding to Peak Across-the-Line Angle (mph)	Peak Across-the-Line Angle (deg)	Peak Along-the-Line Angle Corresponding to Peak Across-the-Line Angle (deg)	Insulator Load Corresponding to Peak Across-the-Line Angle	Standard Deviation of Wind Speed	Standard Deviation of Across-the-Line Angle	Standard Deviation of Along-the-Line Angle	Standard Deviation of Insulator Load	Mean Wind Direction; Sensor #2	Mean Wind Speed (MPH); Sensor #2	Wind Direction Corresponding to Peak Wind Speed; Sensor #2	Peak Wind Speed (MPH); Sensor #2	Precipitation																									
0901045	-2	447	12	20.9	-19	-1.3	291	12	20.5	-20.6	-2.4	332	12	27.7	-20.6	-1.4	332	2.7	3.5	.30	26.20	0	114.9	0	124.2	.01																										
090115	-1	447	12	21.1	-20.3	-1.4	315	12	20	-30.4	-3.9	355	12	20	-30.4	-9	336	2.7	3.2	.7	25.5	0	96.2	0	124.2	25.39																										
09011730	0	447	12	18.7	-17.6	-1.0	317	12	26	-27.9	-6.2	349	12	23.6	-27.9	-4	347	2.1	3.1	1.4	33.40	16	26.9	16	31.7	.01																										
09011745	.2	447	12	16.8	-15	-1.0	319	12	22.1	-25.5	-4.4	399	12	20.2	-25.5	-1	399	2.5	3.3	1.7	30.6	16	23.4	15	28.0	0																										
09011800	.2	447	12	16.6	-16.1	-2.2	324	12	21.9	-25.3	-6.6	490	12	20.6	-25.3	-8	330	2.2	3	2	37.3	12	24.6	16	31.7	25.39																										
09011815	.3	447	12	17	-17.2	-2.3	329	12	27.5	-30	-7.0	450	12	23.4	-30	-8	337	1.3	3.4	2.4	46.3	15	27.0	15	31.7	.01																										
09011830	.4	447	12	15.9	-16.2	-2.3	340	12	21.7	-27.6	-5.5	449	12	19.1	-27.6	-1.0	317	1.9	3.3	1.5	40.7	15	24	15	29.3	25.39																										
09011845	.6	447	12	14.5	-13.9	-2.4	345	12	20.2	-25.0	-4.9	426	12	18.5	-25.0	-1.0	347	.0	3	.6	20.64	16	20.1	16	24.0	0																										
09011900	.5	447	12	14.5	-11.7	-2.2	350	12	19.5	-22.4	-4.1	392	12	18.2	-22.4	-1.0	352	1.6	2.4	.3	12.5	10	19.9	16	29.7	0																										
09011915	.6	447	12	14	-11.2	-2.2	342	12	18.2	-18.2	-2.9	376	12	17.7	-18.2	-2.2	346	1.9	2.4	.40	7.04	10	19.9	10	26.3	0																										
09011930	.6	447	12	13.6	-9.8	-2.4	376	12	17.5	-14.4	-3	391	12	16.6	-14.4	-2.4	372	.4	1.6	.20	10.2	15	16.6	16	22.3	0																										
09011945	.3	447	12	12.7	-8.5	-2.5	387	12	17.9	-12.6	-2.9	400	12	14.6	-12.6	-2.5	389	.50	1	.40	17.4	16	20.5	16	25.3	.01																										
0902000	.7	447	12	11.6	-7.7	-2.6	397	12	14.3	-11.0	-2.9	406	12	13.2	-11.0	-2.5	397	.90	1.2	.40	19.64	16	23.2	16	26.3	25.39																										
0902010	1	447	12	10.8	-5.7	-2.0	404	12	13.7	-9.3	-3	415	12	13.4	-9.3	-3.7	399	1.5	1.2	.40	27.20	16	20.5	16	25.0	0																										
0902030	1.8	447	12	8.8	-4.1	-2.9	414	12	12.4	-6.5	-3.1	446	12	10.1	-6.5	-2.0	410	.40	.9	.30	2.00	3	16.9	3	29.7	0																										
0902045	1.6	447	12	8.2	-3.7	-2.9	417	12	10	-5.2	-3	436	12	9.3	-5.2	-2.0	414	1.60	.4	.30	24.10	10	19.1	19	20.0	0																										
0902100	2	447	12	8.6	-4	-2.9	415	12	10.1	-6.6	-3	421	12	9.6	-6.6	-2.0	414	.90	.3	.30	34.20	10	21.7	10	26.0	0																										
0902115	2.2	447	12	7.3	-3.1	-2.9	419	12	8.0	-3.9	-3	439	12	7.3	-3.9	-2.9	416	1.20	.60	.30	24	14	13.2	15	16.3	0																										
0902130	1.7	447	12	8.3	-4	-2.9	415	12	10.6	-5.7	-3	426	12	9.7	-5.7	-2.0	414	.70	.40	.30	24.1	16	14.3	16	17.0	.01																										
0902145	1.7	447	12	8.1	-3.6	-2.9	417	12	9.0	-6.2	-3	425	12	9	-6.2	-2.9	415	.50	.50	.40	24.10	10	22.4	0	20.7	25.39																										
0902200	1.9	447	12	7.4	-3	-3	420	12	9.1	-3.6	-3	452	12	9	-3.6	-2.9	417	1.60	.80	.40	21.4	17	16.9	17	20.0	.01																										
0902215	2.6	447	12	7.1	-2.9	-3	430	12	8.9	-3.2	-3	457	12	7.4	-3.2	-3	419	1.70	.90	.40	26.9	16	19	16	27.0	0																										
0902230	2.5	447	12	7.5	-2.7	-3	442	12	9.3	-3.5	-3.1	463	12	7.9	-3.5	-2.9	421	.50	.70	.50	34.90	5	23.5	5	30.0	0																										
0902245	2.9	447	12	6.2	-2.6	-3	444	12	8.3	-2.7	-3	481	12	7.2	-2.7	-3	455	.8	.80	.40	22.64	17	20.0	17	27.0	25.39																										
0902300	3.3	447	12	4.8	-2.5	-3	440	12	6.5	-2.6	-3	474	12	5.6	-2.6	-3	470	1.20	.70	.20	30.50	12	23.7	12	34.2	0																										
0902315	3.3	447	12	4.3	-2.2	-3.1	444	12	6	-2.3	-3.1	474	12	4.1	-2.3	-3.1	445	1.10	.30	.40	22.60	12	26.0	0	34.7	.01																										
0902330	3.5	447	12	4.4	-1.5	-3.1	459	12	5.0	-2	-3.1	471	12	4.2	-2	-3.1	444	1.40	.50	.30	24.40	16	27.3	16	34.7	0																										
0902345	2.4	447	12	8.4	2.6	-3.3	429	12	11.5	5.5	-3.7	477	12	11	5.5	-3.5	428	1.6	1.2	.40	27.20	21	20.5	10	31.7	0																										
0910000	3	447	12	6.5	1.7	-3.2	410	12	9.5	4.3	-3.6	456	12	9.2	4.3	-3.2	426	.7	.10	.20	1.40	30	24.9	30	33.3	0																										
0910015	3.5	447	12	5.1	1	-3.2	411	12	7.4	2.5	-3.4	417	12	7.3	2.5	-3.3	415	.70	.60	.40	23.5	29	31.5	27	36.7	0																										
0910030	3.4	447	12	5	.6	-3.1	407	12	6.9	1.6	-3.3	413	12	6.4	1.6	-3.2	406	1.90	.60	.30	22.1	27	35.4	26	41.6	0																										
0910045	3.5	447	12	6.5	.9	-3.2	405	12	9.6	2.1	-3.5	400	12	6.0	2.1	-3.3	399	1.2	.30	.40	36.90	26	37.0	24	43.6	0																										
0910100	3	447	12	8.5	2.1	-3.3	389	12	12.5	4.9	-3.6	400	12	9.3	4.9	-3.2	387	1.2	.6	.40	200	25	33.6	22	43.2	0																										
0910115	2.9	447	12	10.7	3.9	-3.6	365	12	14.6	7.6	-4.5	391	12	14.1	7.6	-3.5	376	1.4	.5	.1	10.64	16	22.6	17	44.5	0																										
0910130	2.7	447	12	9.9	3.0	-4.0	309	12	13.2	6.5	-5.5	339	12	11.4	6.5	-4.9	287	.7	.5	.3	33.20	16	17.9	16	31.7	0																										
0910145	3	447	12	9.6	3.7	-5.5	23	12	13.0	7	-6.4	202	12	13.5	7	-4.9	202	1.10	.4	.3	33.64	16	16.7	16	30.0	25.39																										
0910200	3.1	447	12	9.2	3.5	-6.1	239	12	12.6	6.1	-6.7	250	12	12.1	6.1	-6	252	1	.7	.30	22.6	16	15.0	16	32.2	.01																										
0910215	3.1	447	12	9.6	3.6	-6	220	12	14.1	7.0	-6.7	242	12	10.6	7.0	-6.0	236	1.70	1	.0	35.50	10	15.0	10	25.2	0																										
0910230	2.5	447	12	11.2	4.4	-6.5	215	12	16.4	11.3	-7.2	229	12	15.3	11.3	-6.6	217	2.1	1.2	.1	30.40	16	18.3	16	40.7	0																										
0910245	2	447	12	11.1	4.5	-6.6	210	12	15.0	8.0	-7.2	219	12	13.1	8.0	-6.6	216	1.0	1.1	.40	17.10	16	18.1	16	41.1	0																										
0910300	1.9	447	12	11.0	4.9	-6.6	210	12	18.1	11.1	-7.3	219	12	16.1	11.1	-6.0	219	1.7	1.6	.30	17.10	16	18.0	16	42.2	25.39																										
0910315	2.2	447	12	11.1	3.9	-6.6	208	12	17.9	11.5	-7.6	217	12	17.5	11.5	-7.3	212	1.0	1.5	.20	30.20	16	17.3	16	30.2	0																										
0910330	2.1	447	12	10.2	3.2	-6.6	200	12	16.1	7.4	-7.1	214	12	13.6	7.4	-6.0	211	1.9	.9	.50	30.20	10	15.0	10	33.2	0																										
0910345	2.1	447	12	10.6	3.0	-6.6	207	12	16.1	7.5	-7.1	215	12	16	7.0	-6.7	210	.0	.0	.00	29.60	10	16.1	10	37.7	.01																										
0910400	2.1	447	12	10.1	3.4	-6.6	207	12	14.3	6.9	-7	214	12	11.7	6.9	-6.6	211	1.4	1	.40	29.60	10	15.0	10	34.2	25.39																										
0910415	2	447	12	10.5	3.9	-6.5	207	12	15.2	6.9	-6.9	212	12	13.5	6.9	-6.0	210	1.5	.9	.30	29.60	10	16.5	10	33.2	0																										
0910430	1.3	447	12	10.5	3.4	-6.6	207	12	26.2	10.0	-8.6	232	12	26.2	10.0	-8.5	220	3.3	2.7	.20	29.60	10	15.6	10	40.5	.01																										
0910445	.2	447	12	17.7	10.5	-7.3	213	12	27.6	22	-8.6	234	12	24.3	22	-8.2	223	2.0	2.4	.30	16.5	10	27.3	10	39.3	0																										
0910500	.4	447	12	15.9	9.3	-7	210	12	21.4	15.6	-7.9	226	12	18.0	15.6	-7.1	217	1.2	1.0	.40	17.10	17	23	10	42.6	0																										

FIGURE 11
A TYPICAL DATA RECORD FROM THE ORANGEVILLE TEST SITE

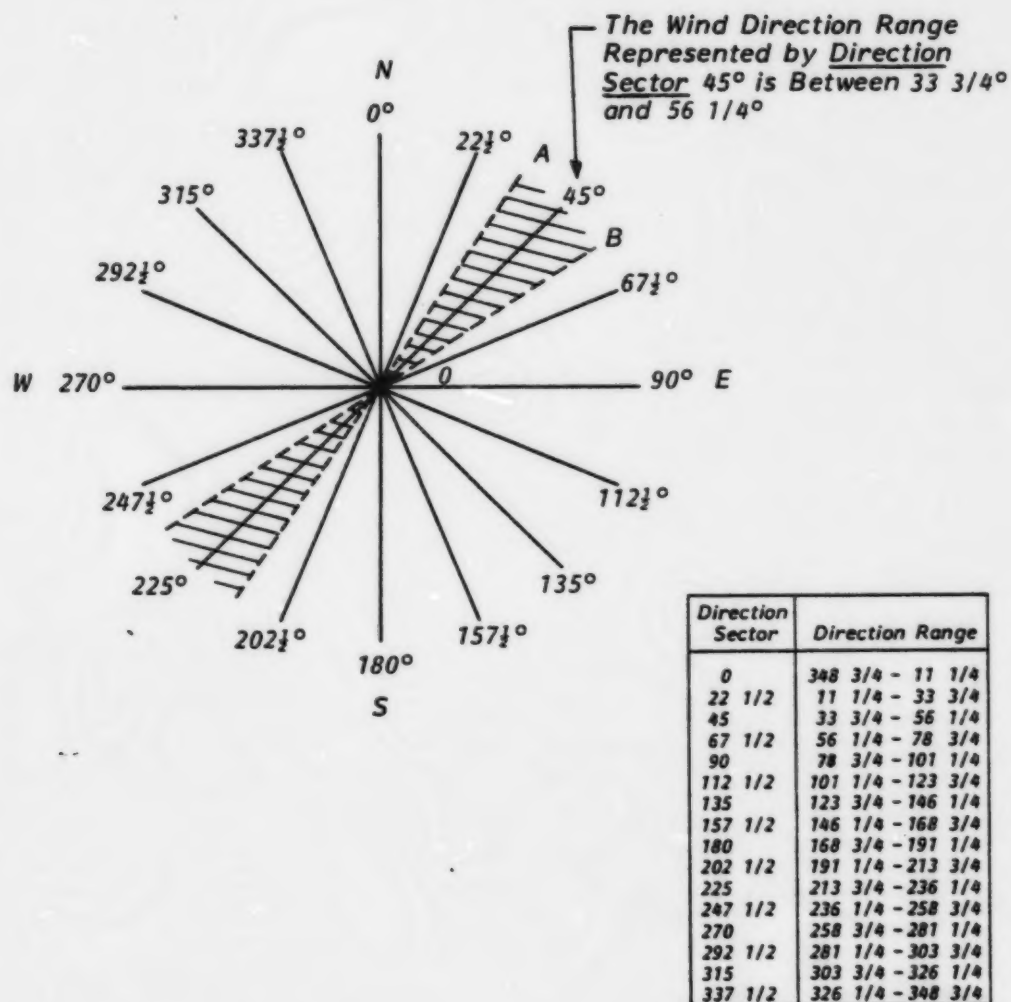


FIGURE 12
WIND DIRECTION COMPONENTS USED AT
THE ORANGEVILLE SITE

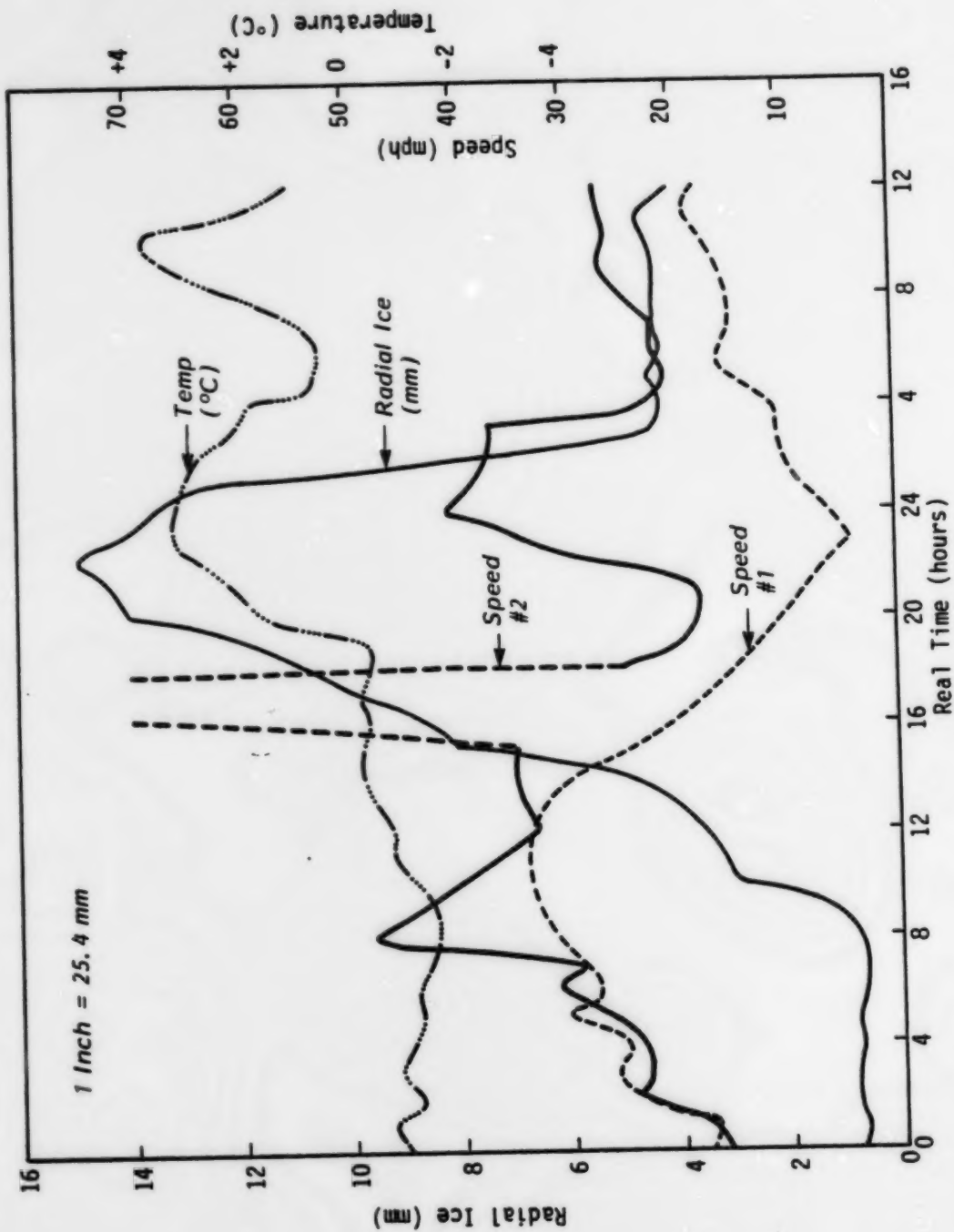


FIGURE 13
DETAILS OF ICE STORM OBSERVED AT THE
ORANGEVILLE TEST SITE ON MAR. 31 - APR 1, 1985